

20. The method of claim 19 wherein the first cap sub-layer has a thickness between 50 and 3,000 Angstroms.

21. The method of claim 20 wherein the second cap sub-layer has a thickness between 50 and 2,000 Angstroms.

22. The method of claim 21 wherein the first cap sub-layer is an oxide layer and the second cap sub-layer is a nitride layer.

23. The method of claim 14 further comprising forming a gate opening through the cap layer to expose a part of the patterned gate metal layer, before the forming an inter-level dielectric layer.

24. A gate structure for MOS devices, comprising:

a gate dielectric layer disposed on a semiconductor substrate;

a metal gate conductor disposed atop the gate dielectric layer;

a cap layer disposed on the metal gate conductor and including overhang portions extending laterally beyond sidewalls of the metal gate conductor;

one or more spacers laterally spaced from the sidewalls of the metal gate conductor and defining air voids beneath the overhang portions, the spacers contacting the cap layer, such that the cap layer and the spacers enclose the metal gate conductor therein; and

at least one self-aligned contact structure formed next to the spacers to be in contact with the semiconductor substrate,

wherein the cap layer and the spacers separate the self-aligned contact structure from directly contacting the metal gate conductor,

wherein the metal gate conductor is laterally recessed, such that an air void is formed between the metal gate conductor and the spacers.

25. The gate structure of claim 24 wherein the metal gate conductor has a thickness between 100 and 3,000 Angstroms.

26. The gate structure of claim 24 wherein the gate metal layer is made of a material including refractory metal, nitrided metal, or silicide.

27. The gate structure of claim 24 wherein the gate metal layer is made of a material including W, Al, AlCu, Cu, Ti, TiSi₂, Co, CoSi₂, Ni, NiSi, TiN, TiW, or TaN.

28. The gate structure of claim 24 wherein the cap layer has a thickness between 50 and 3,000 Angstroms.

29. The gate structure of claim 24 wherein the cap layer comprises at least a first cap sub-layer and a second cap sub-layer disposed thereupon.

30. The gate structure of claim 29 wherein the first cap sub-layer has a thickness between 50 and 3,000 Angstroms.

31. The gate structure of claim 30 wherein the second cap sub-layer has a thickness between 50 and 2,000 Angstroms.

32. The gate structure of claim 31 wherein the first cap sub-layer is an oxide layer and the second cap sub-layer is a nitride layer.

33. The gate structure of claim 24 wherein the metal gate conductor is disposed directly on the gate dielectric layer and further comprising at least one side liner filling the air void between the laterally-recessed metal gate conductor and the spacers, wherein the side liner and the spacer are an integral unit.

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